University of Maine GK-12 Sensors! Program
Benefits a Local Community

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Abstract – Since 2003, University of Maine (UM) GK-12 Sensors! Fellows and Bangor High School (BHS) teachers and students have been addressing community issues for various agencies and organizations in the City of Bangor, Maine. Through GK-12 involvement a community need was identified by teachers, students and emergency service agencies for comprehensive maps of city resources and hazardous material sites to be used in emergency and disaster response planning. GK-12 Sensors! Fellows participate in partnership with Bangor Police and Fire Departments, Bangor Emergency Response Unit and Bangor International Airport, built a geographic information system (GIS) for emergency service providers and produced planning maps. These maps contained locations of all emergency shelters, hospitals, police and fire stations, as well as all known hazardous materials sites within city limits. Other identified community-needs projects included spatial analysis of the incidence of OUI arrests. These activities led to the development of a GIS course at BHS in 2006, one of only a few GIS courses in the U.S. aimed specifically at high school students. Since that time, GK-12 Fellows have assisted students and teachers in other projects based on identified community needs such as spatial analysis of the incidence of teen driving accidents in Bangor and detection of spatial patterns of burglaries for the Bangor Police Department. Currently, students are involved in projects to document burial patterns of a 19th century Irish cemetery using Ground Penetrating Radar and creating walking tour maps of historic ethnic neighborhoods for the Bangor Museum and Center for History and the Bangor Daily News. These highly visible partnerships and resultant products, which raise community and parental awareness of GK-12 Sensors! activities at BHS, may serve to increase interest and support of STEM career pursuits for students.

Index Terms – Community outreach, GIS, GK-12, Secondary school.

BACKGROUND

The GK-12 Sensors! program at Bangor High School (BHS) was established through interactions between Stephen Godsoe, head of the Math Department at BHS, John Vetelino, Professor of Electrical and Computer Engineering at University of Maine (UM) and Constance Holden, a former high school teacher and Instructor in Spatial Information Science and Engineering at UM. Based on the recognition that Maine has historically struggled to attract, retain and develop technology based industries and a sustainable work force for such industries, Godsoe, Vetelino and Holden began to incubate ways that UM and BHS might increase the interest and aspirations of secondary school students to pursue science, technology, engineering, and mathematics (STEM) career paths. Discussions centered on a plan to encourage local high school students and teachers to explore high-tech education and career options through a focus on sensors and sensor-related technologies. They felt a focus on sensors would lend itself to a broad range of secondary school classes which includes math and science courses (e.g. biology, chemistry, physics). The choice of sensors as a central theme was also driven by UM’s reputation as a center for high quality research and innovation in this field. Since March 2002, the team has been awarded multi-year National Science Foundation (NSF) grants: Track I and Track II GK-12 Sensors! and a Research Experience for Teachers (RET) Sensors! grant. The GK-12 Sensors! program selected graduate students from a wide variety of sensor-related science and engineering areas to act as visiting scientists and role models in secondary and middle school classes. A GK-12 Sensors! Fellow is responsible for integrating sensor-related research into existing classroom curricula and provide a positive role model as “scientist” or “researcher” for participating teachers and students. The RET grant provided teachers with experience in sensor research at UM, which enabled them to become strong viable links to local middle and high schools. This paper describes how this partnership has produced outcomes that have not only benefited Fellows, teachers and students but have also had a wider reaching impact within the local community.

HISTORY OF INVOLVEMENT AT BANGOR HIGH SCHOOL

Since 2002, GK-12 Sensors! Fellows have been working with students and teachers in a number of math, science and computer programming classes at Bangor High School.[1] During the 2003-2004 academic year, the UM GK-12 Sensors! team initiated a collaboration with Dr. Kevin Boyle, UM Professor of Resource Economic and Policy, to assist in the development of a social science initiative designed to promote the research and use of sensor data for social science analysis. This interdisciplinary approach had
two primary goals. The first was to introduce students to the widespread use of sensor data, related computer software and methodologies used to integrate sensor data and social science data. There was a strong enthusiasm by the BHS history/civics/geography faculty for investigating emerging technologies and how sensors were shaping students’ opinions and lives. The recognition of increasing reliance on vehicle navigation systems, growth of ubiquitous computing devices, impact of cell-phone based targeted marketing, and expansion of homeland security surveillance technologies made these sensor-related topics accessible and relevant issues for discussion and investigation with the GK-12 Sensors! Fellow’s assistance. The second benefit offered the opportunity to expose students who might not have been interested in advanced STEM subjects to innovative technologies that could be used for investigating cultural or societal topics of interest. Allowing students to conduct self-selected inquiry project provides critical motivation to investigate the science, math and engineering behind these sensor technologies and their impact on the local community and society. Lessons have provided information and materials on current remote sensing satellite networks, digital aerial photography platforms, global positioning systems, and ground penetrating radar technologies. Analyses of sensor-related data and their use in the science of environmental quality monitoring and assessment are used to show how such information is integrated into environmental policy.

This collaborative effort has allowed students in non-STEM classes to explore the science and math behind controversial local, as well as national, issues. An introductory sensor unit was developed in a health class required of all freshmen, encouraging students to consider potential careers in STEM. The goal of this unit was to explore the concept of sensors, their impact on modern life and related careers. Students chose and explored a sensor related career, producing a poster or brochure explaining to classmates the career and associated technologies. Over time, additional STEM related career units were implemented focusing on spatial science and related sensor technologies in a “GIS in Geography” course. BHS teacher Margaret Chernosky and GK-12 Fellow Stacy Doore have developed a GIS Applications and Careers module, first used in 2007-2008, that requires students to research an application area of spatial science and geographic information systems and related sensor technologies as well as specific job descriptions, required education and experience associated with that area of research or industry. Students present their findings to classmates in PowerPoint format. Presentations are archived for use with freshman Geography classes.

The integration of sensors and spatial science into the BHS social science curriculum has evolved over the past five years. Sensor technology topics were initially introduced to Senior Seminar classes, which explore issues of local and national interest. However, in order to increase younger high school students’ exposure to this STEM-related curriculum, and increase the likelihood they would take the math and science classes necessary to be accepted into STEM education paths, in 2005 GK-12 Fellow Judith Walker and Margaret Chernosky developed a classroom curriculum proposal for a permanent BHS GIS course. The course was adopted unanimously by the Bangor School Board. A fully credited course in Geographic Information Systems in Geography was established for the 2006-2007 school year, as well as the inclusion of geographic information system software into many of the freshman and sophomore geography classes.

GK-12 SENSORS! BENEFITS THE LOCAL COMMUNITY: OVERVIEW

GK-12 Sensors! Fellows, teachers and students have worked with Bangor city government and public safety officials since 2004 to identify local needs where their research skills and geospatial and sensor technology could be applied. The contributions to the local community that have resulted from these collaborations have been recognized by local and national organizations. [2] [3] [4] Highly visible partnerships and resultant products continue to provide sustainable evidence of how GK-12-type programs can benefit local communities by serving as a catalyst for community improvement. Teachers at BHS use connections with community leaders to help students take on real-life projects based on local needs. Families of BHS students can see the relevance of the GK-12 program and thereby provide further encouragement to their children to pursue engineering and related science career paths. GK-12 Sensors! Fellows provide the much-needed expertise from their own research areas and play a crucial role in student projects, guiding students through the data collection and design processes, and analysis phases. As “visiting scientists,” Fellows serve as mentors and role models, helping motivate students to strengthen problem-solving skills and inspire them to develop new skills in research and with the technologies used to realize the community-based projects.

METHODOLOGY

In 2007-2008, GIS in Geography adopted an engineering design process model and approached projects as a GIS consulting firm that worked to provide geographic solutions (maps, research, presentations) to community organizations. Students work in teams of two and each student has an individual research focus as well a team responsibility for the duration of the project. Course curriculum explores the engineering design process and its connections to the design of geographic information systems. The class conducts projects based on a GIS Design Process integrating an engineering design model into the class curriculum adapted from a Teach Engineering resource. [5]

The beginning step in any project is for the team(s) to understand the geographic need or spatial question that is being investigated. Project requirements and goals are researched and synthesized. Students determine the data sets needed to address the problem or question and the
limitations of available spatial and non-spatial data. Students also define community-client needs and ascertain whether these needs are the same as those of the intended user of the final maps or GIS. After these requirements are defined, students gather data sets and conduct background research on the spatial questions or community problems they hope to tackle. Teams meet to brainstorm project ideas and imagine how to best design the user interface of images from the GIS for the final visualization of the results. This requires students to investigate existing visualization technology (software, hardware, presentation techniques) keeping in mind the community client needs and requirements.

Once a design has been selected that meets the community client needs and the students' own creative visualization solutions, a design plan is drawn up that outlines the project specifications. This would include preliminary information on the final map layouts, how (and if) the GIS would be accessed by the community client, the essential cartographic and aesthetic elements needed for the final product, how the information would convey the nature of the problem/question and how the presentation will meet the community-client and intended user needs.

The final stages of the project involve students creating the GIS prototype by taking on specific team tasks and building a prototype of the GIS with all spatial and non-spatial data. Once they have confirmed the basic functionality of the GIS, they move on to the visualization and analysis phase, meeting as a team to discuss what works correctly, what aspects are problematic and what improvements could be made. Finally, students revise and improve the GIS design, map layouts, analysis and presentation formats to ensure the quality of the work and that the final product meets community-client requirements and intended audience needs.

Other specific geographic information system concepts and techniques are taught both through direct instruction and within the context of project work throughout the year. GIS symbolization techniques for working with quantitative data, qualitative data and various sensor-related data models are covered in addition to a variety of geometry file creation/modification skills. Most projects require students to use some type of sensor-related technology or sensor data through the use of GPS data, remote sensing technology and data (sensors and satellites). Students learn the importance of organized data management methods and how to research and access existing spatial data sources. GIS applications and careers are an important component of the course curriculum and covered not only in a student research project but also through visits with professionals in those fields from the university and the local community. The course also incorporates the science of geodesy and the mathematics behind map projection systems, exploratory spatial analysis methods with sensor-related data.

As part of the 2007-08 implementation of GIS in Geography, student teams have selected topics for in-depth research based on personal interests, community needs and class presentations. By mid-year, students had acquired skills enough to work independently, with guidance on specific analysis from current Fellow Stacy Doore and teacher Margaret Chernosky. Having students work on various projects targeting their interests and requiring a diverse range of data sets and analysis techniques allows a larger array of community issues to be addressed. Self-determined projects also place more of the responsibility for research and development of the final project on the student, who takes on the role of 'primary investigator' of her/his project. Students develop specific skills based on individual project requirements and are responsible for teaching these skills to classmates after the project is completed. Skill lessons developed by last year's class serve to guide current students; lessons developed this year will be integrated into the instruction of next year's class. The goal is for each year's students to build on the knowledge and skills base of the previous years' students, thus making the course progressively more challenging and the topics and analysis of independent projects more sophisticated.

**GK-12 SENSORS! BENEFITS THE LOCAL COMMUNITY: PROJECTS**

GK-12 SENSORS! fellows and BHS teachers and students have collaborated with Bangor Emergency Services, Bangor Public Safety, local newspaper The Bangor Daily News, and the Bangor Historical Society to involve BHS students in projects with significant impact on and visibility within the community. Each project blends civic involvement and STEM-related learning to achieve practical community needs.

(i) Bangor Emergency Services Project

As part of Homeland Security requirements, emergency service and public safety departments are required to develop emergency response plans. In 2003-2004, students from the BHS Senior Seminar class, under the direction of NSF GK-12 Sensors! Fellows Eeva Hedefine and Bradley Neumann and BHS teacher Jim Smith, investigated various sensor-related topics through a series of introductory lessons on the impact of sensors on daily life and the vital role of sensor-related technology in ensuring public safety. As a result of these lessons, city officials were approached to explore potential avenues of aid the students could provide to the city. Public safety officials were in the process of updating their emergency response plans and did not at the time have the capacity to digitally integrate emergency services data to produce maps for use in the event of a disaster or evacuation. The GK-12 Sensors! Fellows taught students how to design and implement a basic Geographic Information System (GIS) using data available from the Maine Office of GIS. Data was also collected by students on the locations of various facilities and organizations within the city through the use of handheld Global Positioning Systems (GPS) receivers. This led to production of emergency response maps for local public safety personnel that included critical community information such as...
locations of hazardous storage facilities and emergency shelters, and potential evacuation routes. In addition, the GIS provided data on types of hazardous chemicals stored at specific facilities, services available at each emergency shelter, and the number of individuals at each facility, such as a school or adult care facility, that might require assistance in the event of an evacuation. Working mainly after-school, the students were involved in all aspects of the process, from the initial planning and collection of community-based data to the integration of that data into the GIS to produce the final product. Students learned theory and methods related to the design of a dynamic geographic information system and applied this knowledge to produce tangible results that were meaningful to their community. Students presented the completed project to the Bangor police and fire departments in both digital and printed map format. Additionally, the students created a pamphlet showing the location of emergency shelters within the city along with a list of items to bring to a shelter, which was then made available for distribution to all area residents. Students received praise from the Bangor City Council and official proclamations from the Mayor for their service to the Students received praise from the Bangor City Council and official proclamations from the Mayor for their service to the community, and were recognized by the Bangor School Committee.[2] Betsy Webb, currently Superintendent of the Bangor School Department, notes the contributions of this interdisciplinary approach to learning.

“The Bangor School Department is committed to providing the highest levels of inquiry based instruction and the integration of technology to inspire students to pursue higher education experiences in the math, science and engineering fields. The GK-12 Sensors! program and the continuing work of Bangor High School teachers and students in these GIS based classes have not only met this district goal but have also benefited the local community through innovative projects and partnerships.” [6]

(ii) Bangor Public Safety Projects

In 2005, GK-12 Sensors! Fellow Judith Walker and BHS teacher Jim Smith worked with a new after-school Geographic Information Systems (GIS) club, three Senior Seminar classes and three Computer Science classes in designing portable presentations about emergency preparedness and homeland security. These presentations were given to classes of elementary school students in the Bangor area. Each lesson presented basic information on a topic (such as hurricanes) and incorporated emergency response information as well as descriptions of careers relating to the topics. Included in the description of the career was an example of a sensor encountered on-the-job. Each lesson was ‘taught’ by BHS mascot Sam the Ram, the Bangor High mascot.

In 2005-2006 Judith Walker, Eeva Hedefine, Jim Smith and Margaret Chernosky worked with the Bangor Police Department to analyze incidents of “Operating Under the Influence” (OUI) arrests and compare these with the locations of local businesses currently holding liquor licenses. The analysis provided police with identification of specific areas within the city to target with greater resources. In 2006-2007, GK-12 Sensors! Fellow Stacy Doore and Margaret Chernosky in partnership with the Bangor Police Department conducted a geographic inquiry project into the incidence of burglaries in Bangor for the period from 2003-2006. Working with Bill Parker of the UM’s Margaret Chase Smith Policy Center, students learned about various security related sensor technologies as well as research methods used in Crime Analysis such as “hot spot” analysis and the importance of time series visualizations. Student teams investigated the spatial and temporal patterns in burglaries accounting for a number of spatial features and demographic factors. The results of the analyses were presented to and used by the Bangor Police department to identify locations and times where resources were needed to reduce burglary opportunities.

(iii) Bangor Daily News Projects

As a way of making student work more visible to the greater community, teachers and GK-12 Sensors! Fellows have sought out ways to establish a community partnership with the local daily newspaper, the Bangor Daily News. The paper serves as a venue for publishing student work and as a communication vehicle on current student research. In the 2006-2008 school years, GIS students have researched and produced maps for the Bangor Daily News as part of its involvement in the initiative “Newspapers in Education” for National Geography Week. This course kick-off project introduces industry standard software, ESRI ArcGIS 9.2 and the use of a variety sensor and non-sensor related datasets at a larger scale. As students become more proficient with the software and gain more confidence in their skills, students are asked to create maps to be used in conjunction with articles published in both the paper and online editions of the Bangor Daily News. The Bangor Daily News also covers research projects being conducted by the class, such as current research being conducted at the Buck Street cemetery. [7][8] Students report in their journals that one of their favorite aspects of the course is seeing their work taken seriously and having it published in the local newspaper. [9] Eric Zelz, Graphics and Design Editor for the Bangor Daily News, notes the significance of the collaboration with the GK-12 Sensors! program and the students,

“The work this class does for our community, and the Bangor Daily News, is priceless. By presenting our area, and beyond, through insightful maps and thoughtful analysis, they have not only educated themselves but have helped inform our readership of the value of maps and the wealth of stories that they tell. The classes bring an enthusiasm for their work that is contagious, and in presenting their projects on the pages of the Bangor Daily News, we
have improved our product; our Newspapers In Education packages have benefitted greatly through the involvement of the teachers and the students.”[9]

(iv) Bangor Museum and Center for History Projects

In 2004-05, Margaret Chernosky and GK-12 Fellows Bradley Neumann and Eeva Hedefine submitted a multi-class project that was chosen by Environmental Systems Research Institute, Inc. (ESRI), a world leader in GIS software development, as the 2005 K-12 national model. [3] As a part of the nationwide Community Atlas Project competition, BHS’s submission entitled “Historical Geographies of Bangor, Maine” involved substantial community collaboration with the Bangor Museum and Center for History, The City of Bangor (Police, Fire, and Airport), the Departments of Planning and Economic Development, and the Bangor Public Library. Students collected GPS data and used available orthophotos and satellite imagery to map a variety of aspects of Bangor geography. Student-selected topics included the impact of the Fire of 1911 on Bangor’s downtown, evolution of Bangor’s working waterfront, the expansion of Bangor International Airport, and historical urban renewal efforts within the city of Bangor.

In 2007-2008, Margaret Chernosky, GK-12 Fellow Stacy Doore in partnership with instructor Dr. Alice Kelley from the UM Climate Change Institute and local historian John Frawley helped students gather preliminary data to map the site of Bangor’s Buck Street Park, an almost forgotten Irish cemetery. Using GPS units and ground-penetrating radar (GPR), the goal of the class project is to determine whether the park can still be considered a cemetery. The class is looking for signs of disturbance in the soil layers, the presence of buried stone markers, and other evidence of the cemetery’s historic use. Through the analysis of the collected GPR data, students will be able to detect any evidence of coffins through specific types of disturbances in the soil. Students will then be able to create a detailed visualization of the park, highlighting its historic and present boundaries, its surface features and any underground disturbance patterns. The visualizations will be shared with the Bangor Historical Society and the Bangor City Council.

(v) Current projects

Student selected project topics continue to provide interesting applications of course content, opportunities for new skills acquisition and community partnerships. Current project topics, which require a variety of social as well as sensor-related data sets, are listed below:

- Impact of Sea Level Rise Along the Coast of Penobscot Bay, Maine
- Bangor Waterways: Demographic, Industrial and Developmental Pressures
- Historical and Predictive Analysis of Presidential Election Results by Voting District for Bangor
- Daycare Accessibility for Low Income and Single Parent Families in Bangor
- Marketing Bangor’s Harbor and Waterfront: Historical and Modern Features to attract Recreational Sailing and Tourism

STUDENT LEARNING AND PERCEPTIONS

This ‘outside of the box’ strategy of deploying an engineering design model and engineering concepts in a non-STEM class that benefits the local community appears to have also motivated students to consider pursuing more STEM related fields. This suggests that providing this type of inquiry based learning experiences in non-STEM settings may be key to increasing STEM interest and motivation for some students. Throughout the past two years, the BHS GIS and Geography classes have been asked to provide informal feedback on their learning and their perceptions on the class format. The purpose of the informal surveys and journal entries was to collect student perceptions of academic classes and their post-secondary plans as well as their thoughts on what they were getting out of the course throughout the year.

In an informal end of year survey given to the 2006-2007 classes (N=63), although 50% of students reported that classes in math and science were their least enjoyable classes, 81% of the students reported they enjoyed GIS based classes more than any other content area,[10] This would seem to be a contradiction in student responses, considering students indicated enjoying the GIS class with a heavy emphasis on engineering concepts but did not report enjoying their math and science classes which are essential components of the field of engineering.

The interpretation of this contradiction is assisted by looking at related student feedback from journal entries about the GIS class and its content. Student journal entries illustrated that the students enjoyed having the chance to try on different project team roles and valued the inquiry based approach to the class. Students also responded that they liked the fact that their work was taken seriously in the community and often published in the Bangor Daily News. Consistently, students reported they would recommend the class to friends, especially to those interested in “working hard” and those who might be interested in engineering or computer science. “I would recommend this class to friends for next year because I think that learning how to use the GIS software could be helpful. I would definitely recommend this class for friends that are interested in engineering courses in college.” [10][11] Students reported they had learned more about the field of engineering through the in-class, self-directed and community-based projects and engineering now looked “interesting,” “fun” or
“exciting”. Some students reported that they now thought that pursuing an engineering field was something they could do because they realized they had good grades in the math and science classes that would be required to get into an engineering program. Students also indicated that because of the course content they now understood that there were many sub-fields of engineering and they were more open to thinking about engineering as a possible career path.

In short, student responses indicated that students have responded positively to the infusion of applied STEM content through the vehicle of GIS based classes and valued the opportunities for self selected research projects that are meaningful to their own lives and issues within their local community.

CONCLUSION

The GK-12 Sensors!-BHS collaboration has positively impacted civic agencies and organizations in the City of Bangor, Maine, by generating or modernizing products and services. Emergency service agencies and the Bangor International Airport have been provided with comprehensive digital maps for emergency and disaster response planning. Bangor Police can now use GIS to analyze spatial and temporal patterns of incidents of OUI (“Operating Under the Influence”) arrests and burglaries. GIS students have produced maps for the local newspaper, Bangor Daily News, and have a permanent feature, “Ethnic Bangor,” on the newspaper’s website. Working with the Bangor Historical Society, The City of Bangor (Police, Fire, and Airport), the Departments of Planning and Economic Development, and the Bangor Public Library, “Historical Geographies of Bangor, Maine” was chosen as a national model for GIS-based community projects.

The success of this community outreach model relies on the following elements:

- GK-12 Fellows work with high-school teacher to build project-based curriculum using an established engineering design process model
- Student project-teams are treated as GIS consulting firms working to provide geographic solutions (maps, research, presentations) to community organizations
- Community agencies are directly involved with students, teachers and Fellows to identify areas of need and available resources, and remain engaged throughout process

Students learn in an applied context that fosters both personal and civic responsibility. The GK-12 Fellow serves as an in-class STEM role model and as a project facilitator, assisting both teacher and student. The interaction of municipal personnel with students, teachers and fellows is the constitutive dynamic of the community outreach effort. As communities inherently have interest in and willingness to strengthen its school system, the model described here of generating curricular materials from community needs and producing highly visible, positive impacts on the community is a model that can be adapted to the needs of communities, whether rural, suburban or urban.

REFERENCES


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